Comparison of Manual and Electronic Traceability in Swine Production

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ABSTRACT

Food safety is an important issue in animal production chain and the use of traceability in swine production is the first step to meet the new consumer's demands towards the era of identity preserved for agricultural products. In order to proceed with the traceability the animal's (individual or group) identification is necessary. Some events in the swine production chain are relatively easy to register electronically while others require special ability in handling. Nowadays in Brazilian swine production most records are kept manually and this introduces an undesirable degree of error. Conventional modeling tools that depend upon one criterion to select among possible alternatives have limitations. This research compares both manual and electronic traceability using AHP (Analytical Hierarchy Process) as a decision making tool. The results showed a higher score for the alternative of electronic traceability for both management events' nature: qualitative or quantitative.

Keywords: traceability, Analytical Hierarchy Process, swine production management

1. INTRODUCTION

The "farm to fork" strategic approach in integrated animal production system as suggested by the White Paper on Food Safety (2000) is designed to cover the entire food chain. It contains all elements of the food production chain including the health, management and welfare of animals. Traceability can be achieved either manually or electronically, or yet using both alternatives depending on the event to be registered and the accessibility of a specific tracking technology. However, the decision of choosing a certain way of tracking data is not easy mainly due to the nature of the specific management task as well as to the economical and technological feasibility.

A systematic method of accumulating required data, both measurable and investigative, needs to be established in order to properly analyze the weak points in a production chain as well as to properly measure the health status of the animals. The first step in order to accurately follow the complete food chain traceability relies on the animal's identification (ID). The technology of identifying animals is not new. Animals have been identified long ago for proof of ownership; only lately with the urge to document origin and implement the traceability process, identification has become an essential need. Lopes (1997) considers the electronic ID the safest identification. Processes to automatically recognize the identity of an animal are a reliable technology, and electronic identification systems show great performance potential at this time. They are not only used for process control on farms, but can also be successfully implemented for control tasks such as animal or disease monitoring, or administrative purposes (Artmann, 1999). There are, however some technical problems regarding the practical aspects of electronic identification such as the removal of the transponders during slaughter (Stark et al., 1998). When comparing electronic and manual identification in pigs the authors found higher error index for the manual ID. Swine production control when done manually may generate unreliable information from mistakes in reading and writing data (Malucelli et al., 2000). New transponder technology has been developed both for injected devices as well as used in ear tags in order to assure a reliable swine identification.

The multi-criteria decision-making method (MCDM) frameworks have been previously applied to a number of analysis and planning problems including the analysis of animal production issues and systems. The analytic hierarchy process (AHP) is a technique often used to model subjective decision making processes based on multiple attributes (Saaty, 1980). It is based on three principles of decomposition, comparative judgments, and synthesis of priorities. The first step begins by structuring the hierarchy to capture the basic elements of the problem. The second step calls for developing a matrix to carry out pairwise comparisons of the elements in a level with respect to all the elements in the level above. The third step of the AHP is to synthesize priorities from the second level down by multiplying local priorities by the priority of their corresponding criterion in the level above and adding them for each element in a level according to the criteria it affects.

The AHP as a growing field in both its theoretical and applied ramifications has been applied widely in decision making (Saaty and Vargas, 2001; Zahedi, 1986). One of the topics on which research concentrates is the problem of prioritization of technology. AHP technique is widely used in both individual and group decision making environments.

Dyer and Foreman (1992) elaborated on the suitability of AHP for group decision making in different types of contexts. Application of AHP in group decision making environments involves defining a common hierarchy of factors (or criteria), specifying pair-wise comparisons by members of the group and aggregation of those pair-wise comparisons for the entire group.

In general, models defined using the AHP technique can be used for two purposes: to support ranking of decision alternatives as part of a specific individual or group decision making activity, or to model subjective preferences of an individual or a group of decision makers to build a decision support system (DSS) to assist repetitive decision making activities. Bolloju (2001) addressed the application of AHP for the purpose of solving a specific category of decision problems that involves different decision makers solving similar questions independently.

There are four basic approaches that a group can use to set the weights of elements in a hierarchy: consensus, vote or compromise, geometric mean of the individual judgments, and weighted arithmetic mean. To illustrate these four approaches, let a_{ij} denote the comparison of element i to element j in pair-wise comparison matrix A and suppose there are n decision makers. In the first approach, the group of decision makers is required to reach a consensus on each entry a_{ij} in A. If the group is unable to reach a consensus, then a vote or compromise is used in the second approach to set the entry's value. In the third approach, let a_{ij}^k denote the comparison of element i to element j for decision maker k(k=1,2,...,n) in pair-wise comparison matrix A.

The individual judgments of the n decision makers are combined using the geometric mean to produce the entry:

$a_{ij}=[a_{ij}^{1}\times a_{ij}^{2}\times\cdots\times a_{ij}^{n}]^{1/n}$ Equation 1 (Bolloju, 2001).

If weight w^k is assigned to decision maker k, then the weighted arithmetic mean
$a_{ij}=w^1a_{ij}^{1}+w^2a_{ij}^{2}+\cdots+w^na_{ij}^{n}$ Equation 2 (Bolloju, 2001)
has also been used to combine the judgments of decision makers. In these approaches, the group needs to decide on the weight for each decision maker.

Given a decision making problem to determine the priorities of the interdependent alternatives, it is necessary to estimate two kinds of forecasts for their occurrence probability (initial and conditional probability or weight) with the help of experts, for their relative importance on technology may change according to their occurrence. Initial probabilities or weights indicate that the alternatives under consideration are estimated without considering any of the other alternatives. This again consists of two kinds of probabilities, those of occurrence and those of non-occurrence which is $[1-P(\text{occurrence of alternative})]$. Conditional probabilities mean that an alternative occurs, given that some other alternative has occurred. These probabilities show the impact that the occurrence of any alternative has on the probability that any other alternative will occur. Just as the occurrence of an alternative can affect the probability that another will occur, its nonoccurrence can have a similar impact.

Aczél and Saaty (1983) have shown that the geometric mean preserves the reciprocal property in the combined pair-wise comparison matrix. The geometric mean is the most common approach used by groups to set priorities (Condon et al, 2003). Petersen et al. (2002) describe a model for using in swine production where a computerized health management system is applied in the entire production chain from breeding to slaughter. The model is structured according to the data recording, processing and exchange of information between farms, abattoir and the consulting service. It is shown that expert feedback is essential in the decision making process.

Considering the importance of establishing strategies for the use of traceability in Brazilian swine production management, the aim of this research was to develop a decision making plan for the choice of the use of manual and/or electronic traceability, using the AHP technique.

2. MATERIALS AND METHODS

The experiment was carried out at a commercial swine farm located in Brazil, at 23º12' latitude South, and 47º17' longitude West, at an altitude of 521m. The tested alternatives were: electronic system (using implanted transponder and manual reader), total manual system (using written recording control data) and the mixed system (using quantitative data recorded manually-such as weight). During the first step the decision problem was disaggregated into a hierarchy of interrelated decision elements or attributes. The most macro-decision objective lied at the top of the hierarchy, while the lower levels of the hierarchy contained more detailed descriptions of attributes or groups of attributes that contribute to the quality of the choice between alternatives. For the specific system to be considered good it was necessary to meet the manager and labor needs, as suggested by Petersen et al. (2002). The criteria considered important were: information security and reliability; the system needed to be practical, and the system needed to be easy to implement and fast in retrieving information.

Information from management was collected from three specialists. Each criterion was defined after ten repetitions of the questions in order to build up consistent matrices (consistent factor > 0.1). The method used was by voting for the best option, regarding the tasks involved Bolloju (2001). The basic found matrix is shown in Table 1. Table 2 shows the normal criteria AHP matrix.

Table 1. AHP criteria matrix (intensity of importance)

	Security and reliability	Practice	Fastness
Security and reliability	1	5.000	8.000
Practice	0.200	1	3.000
Fastness	0.125	0.250	1
Total	1.325	6.250	12.000

Table 2. AHP normal matrix of criteria

	Security and reliability	Practice	Fastness
Security and reliability	0.754	0.800	0.666
Practice	0.150	0.160	0.250
Fastness	0.094	0.040	0.083

During the first step the decision of using either electronic or manual traceability or a mixture of both systems was disaggregated into a hierarchy of interrelated decision elements. Further, the choices were organized in similar attributes, developing an unbiased scoring for aggregation. The second and third steps result in the pair-wise comparison of decision elements and the estimation of decision weights by one of several methods. Finally, the weights developed at each level of the hierarchy were aggregated into an overall ranking for an alternative, and the alternative with the highest score was considered dominate (Zahedi, 1986; Saaty and Vargas, 2001). The challenge was reaching agreement among the participating decision makers on value judgments of the importance of attributes, which was implement by the manager and workers participation in the research.

The level of consistency of each computed criteria matrix was calculated and the evaluation of the hierarchy importance was established. This estimate was calculated by Equation 3:

$\lambda_{máx}=T * w$ Equation 3 (Saaty (1977),
where w (weight of decision) is calculated by adding the matrix and T is the vector found in step three (Bolloju, 2001). The consistency index (CI) is given by Equation 4:

$CI = (\lambda_{máx}–n)/(n–1)$ Equation 4 (Saaty and Vargas, 2001),
where n is the number of criteria. CI was compared with the Random index (RI), as shown in Saaty (1977). For perfect comparisons CI=0 and $\lambda_{max}=n$. Inconsistent assumptions occur when $(C.I./R.I.)\geq 0.1$. Mathematical calculations were made using Excel®.

Two sets of animals were used in the trial: (a) 20 sows in the gestating building and (b) 50 piglets 25 days old which were randomly chosen, their weight were recorded at day one and at day 25th and the feed conversion was calculated. Weight gain and feed conversion were considered quantitative variables while vaccination of both sows and piglets and sows oestrus identification and insemination were considered qualitative events. Within the population of piglets in the trial, a sample of five piglets was randomly considered for identification. Afterwards a determination of the ideal sample size was calculated on the basis of the desired error. The piglets and sows were identified using a transponder implanted in the ear and the electronic recording was done using portable antennae that read and store data, which was unloaded afterwards at the computer.

In the sows management each event was identified by a color card with a transponder glued to it. The management consisted of the worker registering the event (weighting, vaccination, medication, oestrus or insemination) and the animal involved in it. Records of the amount of time each worker (two) took for recording data (Silva et al, 2004) both manually and using the antennae were kept. The recorded data was related to the identification, vaccination and weighting of the piglets, and vaccination, medication, oestrus identification and insemination of sows. The average time spent for registering and unloading of both electronic and manual data was compared using the T test, and analyzed by interpreting the Boxplot graphics.

3. RESULTS AND DISCUSSION

In order to select the right piglet's weight sample size it was necessary to choose the precision of the estimative desired. It was agreed with the two specialists that the smaller the error the better and the larger the sample the smaller the error introduced in the results. It was also agreed that an acceptable error would be 0.34, at a confidence interval of 95%. Equation 5 shows the mathematical representation of the weight average of the sample.

$$\overline{P} \pm Error \text{ or} \left(\overline{P} - Error < \overline{P}pop. < \overline{P} + Error\right) = CI = 95\% \qquad \text{Equation 5}$$

(Silva et al., 2004), where $\overline{P} =$ average of the sample weight; *Error* = error of the sample (±0.34); $\overline{P}pop =$ average of the total population weight, and CI = confidence interval. Five piglets and five sows were weighted to find the variance (*dp*). The values of *Error* and *dp* were then applied in Equation 6 and the ideal sampling value was found:

$$n = \left(\frac{1.96 * dp}{Error}\right)^2 \qquad \text{Equation 6 (Silva et al., 2004)}$$

where *n* = sample value; *dp* = estimated variance value; and *Error* = desirable error (defined by the manager)

The criteria matrices were built and the ranking values calculated similarly to the arrangement proposed by Condon et al. (2003). Table 3 shows the computed ranking of each criterion and the calculated average value designed for it. Given this ranking it was decided that the most important criterion was *security and reliability* (0.740), followed by *practice* (0.186), and finally by *fastness* (0.072).

Table 3. Ranking criteria and calculated matrix average values

Criteria	Ranking
Security and reliability	0.740
Practice	0.186
Fastness	0.072

Tables 4a and 4b show the alternative matrix for *security and reliability*, and it was found that the score for the criterion was higher in the system using electronic tools (0.711), followed by mixture of electronic and manual system (0.205), and by the manual system (0.082).

Table 4a. Matrix of alternatives for the criterion security and reliability

Alternative	Electronic	Manual	Electronic and Manual
Electronic	1	8.000	4.000
Manual	0.125	1	0.333
Electronic and Manual	0.250	3.000	1
Total	1.392	12.000	5.333

Table 4b. Ranking of score of the alternatives for the criterion security and reliability

Alternative	Score
Electronic	0.711
Manual	0.082
Electronic and Manual	0.205

Tables 5a and 5b present the matrix of alternative for the criterion *practice*, and the ranking of scores, respectively. The ranking of scores show that for this criterion the best option was the electronic (0.647) followed by the electronic and manual (0.229) and manual (0.122).

Table 5a. Matrix of alternative for the criterion practice

Alternative	Electronic	Manual	Electronic and Manual
Electronic	1	5.000	3.000
Manual	0.200	1	0.500
Electronic and Manual	0.333	2.000	1
Total	1.533	8.000	4.500

Table 5b. Ranking of scores of the alternatives for the criterion practice**.**

Alternative	Score
Electronic	0.647
Manual	0.122
Electronic and Manual	0.229

In Tables 6a and 6b both the matrix of alternatives and the ranking of scores for the criterion *fastness* are presented respectively. It was found that for this criterion the recording and transferring of data by using electronic traceability was faster (0.713) than the mixed choice (0.219), followed by the manual recording and transferring of data (0.066).

Table 6a. Matrix of alternatives for the criterion fastness

Alternative	Electronic	Manual	Electronic and Manual
Electronic	1	9.000	4.000
Manual	0.111	1	0.250
Electronic and Manual	0.250	4.000	1
Total	1.361	14.000	5.250

Table 6b. Ranking of score of the alternatives for the criterion of fastness

Alternative	Score
Electronic	0.713

Manual	0.066
Electronic and Manual	0.219

In Table 7 the final matrix for the alternatives and the respective criteria scores is presented, and Table 8 shows the final ranking of scores for each alternative.

Table 7. Final matrix Alternative *versus* Criterion.

	Security and reliability	Practice	Fastness
Electronic	0.711	0.647	0.713
Manual	0.082	0.122	0.066
Electronic and Manual	0.205	0.229	0.219

The alternative with the highest score is considered the best alternative as shown by Zahedi (1986), and Saaty and Vargas (2001). Therefore for this experiment, the system with electronic traceability was chosen as the best alternative (score=0.699). The second choice by the score ranking was a mixture of electronic and manual alternative (score=0.211). Here the electronic recording alternative was defined for qualitative jobs such as vaccination and tooth trimming for piglets, and vaccination and insemination for sows. This result agrees with Stark et al. (1998).

Proceeding with the consistence calculation (CI/RI), it was found that the matrix values were logically related.

Table 8. Matrix solution (Alternative X Criterion)

Alternative	Score
Electronic	0.699
Manual	0.089
Electronic and Manual	0.211

During data recording the positions the sows were at the time of recording influenced the necessary recording time in both systems. When they lay with the ears away from the reading position, the time spent trying to reach the ID transponder was higher than when the animals had they head facing the drinker or standing up. The average time the workers used for recording each electronic ID using the manual antenna/reader was 2s. The average time spent for typing all data into the computer manually was in average 13 min, while unloading of the antenna/reader’s data was in average 3s.

4. CONCLUSION

The AHP was ideal for the support of the formulation of strategies in this area. Regarding traceability (not considering cost) the best and most reliable system was the electronic data recording. This system presented the best alternative in terms of security and reliability as well as practice and fastness in both recording and data processing.

5. ACKNOWLEDGMENTS

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